

Executive Summary

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**Sand Resources, Regional Geology, and Coastal
Processes of the Chandeleur Islands Coastal
System: an Evaluation of the Breton National
Wildlife Refuge**

Scientific Investigations Report 2009–5252



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Edited by Dawn Lavoie

In cooperation with the U.S. Fish and Wildlife Service

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**U.S. Department of the Interior
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Executive Summary

By Dawn Lavoie¹

Abstract

Breton National Wildlife Refuge, the Chandeleur Islands chain in Louisiana, provides habitat and nesting areas for wildlife and is an initial barrier protecting New Orleans from storms. The U.S. Geological Survey (USGS) in partnership with the University of New Orleans Pontchartrain Institute for Environmental Sciences undertook an intensive study that included (1) an analysis of island change based on historical maps and remotely sensed shoreline and topographic data; (2) a series of lidar surveys at 3- to 4-month intervals after Hurricane Katrina to determine barrier island recovery potential; (3) a discussion of sea level rise and effects on the islands; (4) an analysis of sea floor evolution and sediment dynamics in the refuge over the past 150 years; (5) an assessment of the local sediment transport and sediment resource availability based on the bathymetric and subbottom data; (6) a carefully selected core collection effort to ground-truth the geophysical data and more fully characterize the sediments composing the islands and surrounds; (7) an additional survey of the St. Bernard Shoals to assess their potential as a sand resource; and (8) a modeling study to numerically simulate the potential response of the islands to the low-intensity, intermediate, and extreme events likely to affect the refuge over the next 50 years.

Results indicate that the islands have become fragmented and greatly diminished in subaerial extent over time: the southern islands retreating landward as they reorganize into subaerial features, the northern islands remaining in place. Breton Island, because maintenance of the Mississippi River-Gulf Outlet (MRGO) outer bar channel requires dredging, is deprived of sand sufficient to sustain itself. Regional sediment transport trends indicate that large storms are extremely effective in transporting sand and controlling the shoreline development and barrier island geometry. Sand is transported north and south from a divergent zone near Monkey Bayou at the southern end of the Chandeleur Islands. Numerical simulation of waves and sediment transport supports the geophysical results and indicates that vast areas of the lower shoreface are affected and are undergoing erosion during storm events, that there is little or no fair weather mechanism to rework material into the littoral system, and that as a result, there is a net loss of sediment from the system. Lidar surveys

revealed that the island chain immediately after Hurricane Katrina lost about 84 percent of its area and about 92 percent of its prestorm volume. Marsh platforms that supported the islands' sand prior to the storm were reduced in width by more than one-half. Repeated lidar surveys document that in places the shoreline has retreated about 100 m under the relatively low-energy waves since Hurricanes Katrina and Rita; however, this retreat is nonuniform.

Recent high-resolution geophysical surveys of the sea floor and subsurface within 5–6 km of the Chandeleur Islands during 2006 and 2007 show that, in addition to the sand that is rebuilding portions of the island chain, a large volume of sand is contained in Hewes Point, in an extensive subtidal spit platform that has formed at the northern end of the Chandeleur Islands. Hewes Point appears to be the depositional terminus of the alongshore transport system. In the southern Chandeleurs, sand is being deposited in a broad tabular deposit near Breton Island called the southern offshore sand sheet. These two depocenters account for approximately 70 percent of the estimated sediment volume located in potential borrow sites. An additional large potential source of sand for restoration lies in the St. Bernard Shoals, which are estimated to contain approximately $200 \times 10^6 \text{ m}^3$ of sand.

Successful restoration planning for the Breton National Wildlife Refuge should mimic the natural processes of early stages of barrier island evolution including lateral transport to the flanks of the island chain from a centralized sand source that will ultimately enhance the ability of the islands to naturally build backbarrier marsh, dunes, and a continuous sandy shoreline. Barrier island sediment nourishment should be executed with the understanding that gulf shoreline erosion is inevitable but that island area can be maintained and enhanced during retreat (thus significantly prolonging the life of the island chain) with strategic sand placement.

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Breton National Wildlife Refuge comprises a number of Louisiana barrier islands trending north-south from the northern Chandeleur Islands to Breton Island in the south. In addition to providing habitat and nesting areas for

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endangered species (for example, brown pelican [*Pelecanus occidentalis*], least tern [*Sterna antillarum*], piping plover [*Charadrius melodus*]) and other wildlife species (nesting and wading birds, waterfowl, rabbits, raccoons, and loggerhead sea turtles [*Caretta caretta*]), the refuge provides an initial barrier to storms for the southeastern Louisiana wetlands and is a fundamental component of the geomorphologic features that protect the metropolitan New Orleans area. The refuge has been impacted by hurricanes throughout history but never as severely as by Hurricanes Katrina and Rita in 2005. The severity of damage brings into question what the future configuration of the island chain will be, what protective function the islands will provide for the mainland wetlands and New Orleans, and whether the refuge can continue to provide the same level of functional habitat for endangered species and other wildlife as it did prior to the 2005 hurricanes.

The U.S. Geological Survey (USGS) in partnership with the University of New Orleans Pontchartrain Institute for Environmental Sciences undertook an intensive year-long study to provide the U.S. Fish and Wildlife Service (USFWS) with information needed to answer these questions and make management decisions relating to the future of the Breton National Wildlife Refuge. The effort built on a previous bathymetric data collection effort funded by the Louisiana Coastal Area Science and Technology Program (jointly funded by the Louisiana Department of Natural Resources and the U.S. Army Corps of Engineers) that surveyed all of the sandy shorelines of Louisiana. The USFWS effort included (1) an analysis of island change based on historical maps and remotely sensed shoreline and topographic data; (2) a series of lidar surveys at 3- to 4-month intervals after Hurricane Katrina to document barrier island recovery; (3) a discussion of sea level rise and its effect on the islands; (4) an analysis of bathymetric data to document sea floor evolution and sediment dynamics in the refuge over the last 150 years; (5) an assessment of the local sediment transport and sediment resource availability based on bathymetric and subbottom data; (6) a carefully selected core collection effort to ground-truth the geophysical data and more fully characterize the sediments composing the islands and surrounds; (7) an additional survey of the St. Bernard Shoals to assess their potential as a sand resource; and (8) a modeling study to numerically simulate the potential response of the islands to the low-intensity, intermediate, and extreme events likely to affect the refuge over the next 50 years. Results from these efforts can be found in the eight chapters (chaps. A–H) that form the main body of this report. The main conclusions of the team can be found in the final synthesis chapter (chap. I). Metadata and information used to support the conclusions in each chapter can be found in the appendixes.

Chapter A. Shoreline Change

Of the more than 50 hurricanes that have impacted the Breton National Wildlife Refuge during the past century, 9 were severe. An analysis of shoreline change as a function of hurricane impacts clearly demonstrates that the erosional damage caused by the passage of Hurricane Katrina in 2005 was extremely large when compared with the shoreline erosion that resulted from all of the other hurricane passages during the 20th century. During the 20th century the Chandeleur Islands were characterized by shoreline erosion and island arc rotation due to varying rates of erosion along the shoreline. Between 1922 and 2004, the average rate of erosion was about 35 ft/yr. The amount of erosion due to Hurricane Katrina was an unprecedented 661 ft during the short time period of the hurricane's passage. Simply extrapolating the measured data in a linear fashion with appropriate error bars shows that the islands may persist until about 2064 if there are no future storms the magnitude of Hurricane Katrina. The islands may, however, become shoals or disappear entirely between 2013 and 2037 if one more Katrina-like storm affects the islands.

Chapter B. Recovery Potential

For nearly 2 years after Hurricane Katrina in 2005 removed 86 percent of the surface area of Louisiana's Chandeleur Islands, most of the island chain continued to erode rapidly. Feedback processes triggered by the hurricane enhanced this erosion even under relatively mild, poststorm conditions and pushed the island chain closer to complete submergence.

Lidar surveys revealed that the island chain immediately after Hurricane Katrina lost about 84 percent of its area and about 92 percent of its volume in comparison to the area and volume of the islands in 2002 (after Hurricane Lili). Peak elevations were reduced from more than 6 m to less than 3 m, and the marsh platforms that supported the islands' sand prior to the storm were reduced in width by more than one-half. During Katrina, all of the sand visible from the air was removed from the island, leaving only marshy outcrops. No dunes or beaches survived the storm. Sea, Lake and Overland Surges for Hurricanes (SLOSH) model calculations of storm surge compared to lidar elevations on the island show that the islands went entirely underwater during the later stages of the storm and were essentially a submerged shoal as opposed to a situation where waves simply lapped over the tops of the islands. USGS aerial photograph surveys 2 months after the storm showed conclusively that the island was still eroding rapidly after the storm, although some of the subsequent

erosion may have been caused by Hurricane Rita, which made landfall in September 2005. Repeated lidar surveys document that in places the shoreline has retreated about 100 m under the relatively low-energy waves since Hurricanes Katrina and Rita; however, this retreat is not uniform. In other places (about 44 percent of the gulf shoreline) spits and welded swash bars have built the shoreline seaward.

The Chandeleur Islands are sand starved. Their original source of sand was a delta lobe deposited by the Mississippi River; however, about 1,800–2,000 years ago, the Mississippi River changed course, cutting off the sediment supply to the delta lobe. As the lobe eroded landward from lack of new sediment, it also compacted from its own weight, leaving the beach detached from the mainland and forming the remnant barrier islands of the Breton National Wildlife Refuge. With continued subsidence and sand starvation, the islands are forecast to become smaller and lower and eventually sink beneath the sea. The eventual demise of the Chandeleur Islands will depend on the frequency and/or intensity of future storms and the rate of sea level rise.

Chapter C. Potential Effects of Sea Level Rise on the Chandeleur Islands

Coastal regions are characterized by dynamic landforms and processes because they are the intersection between land, ocean, and atmosphere. The global climate is changing because of large population increases, the burning of fossil fuels, and land-use change over the past century. Warming of the global climate is unequivocal, but the effects of climate change are highly variable across regions and difficult to predict with high confidence when they are based on limited observations. Features such as barrier islands, bluffs, dunes, and wetlands constantly undergo change because of driving processes such as storms, sediment supply, and sea level change. Sea level rise will have profound effects by increasing flooding frequency and inundating low-lying coastal areas, but other processes such as erosion and accretion will have cumulative effects that are profound but not yet predictable. The consensus in the climate science community is that relative sea level rise (the combination of sea level rise and the land sinking) for the northern Gulf of Mexico coast is much greater than the average global sea level rise. Two direct effects of atmospheric warming on the Chandeleur Islands and other coasts are accelerated sea level rise and a likely increase in storm intensity. Recent scientific opinion holds that coastal landforms such as barrier islands, including the Chandeleur Islands, have tipping points from sea level rise and storms. Once this point is reached, rapid and irreversible change happens to the islands.

Coastal regions are often managed under the premises that sea level rise is not significant, that shorelines are static or can be fixed in place by engineering structures, that storms are regular and predictable, and that the physical processes driving coastal change are linear. The new reality of sea level rise and increased storminess due to climate change requires an understanding that coasts and barrier islands are dynamic and are best maintained by allowing natural processes to function.

Chapter D. Sea Floor Evolution and Sediment Dynamics

Shoreline and sea floor change analyses based on historical hydrographic data (dating from 1863), shoreline surveys (dating from 1855), and satellite imagery of the Chandeleur Islands reveal long-term trends of barrier shoreface retreat, barrier thinning, and recently, barrier disintegration. Volume calculations indicate that about $150 \times 10^6 \text{ m}^3$ of sediment has been deposited northward and seaward off Hewes Point, La., during the past 125 years. A similar volume of sediment has accreted at the extreme southern limits of the island chain (south of Breton Island); however, the volume deposited in the backbarrier (behind the islands) is only half that distributed to the flanks. The dominant transport direction is north and south from a midpoint (near Monkey Bayou [see location in fig. 4 in chap. D]) in the island chain. The depositional sinks at the flanks of the island arc accreted at rates of more than $1 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$ between 1870 and 2007. The sediment sources for these accretionary zones at the flanks include (1) relict deltaic deposits eroded from the shoreface where about $790 \times 10^6 \text{ m}^3$ of erosion has occurred since 1870 and (2) nearshore and subaerial barrier sand. Long-term shoreline erosion and submergence of the islands are driven by pulses of rapid land loss triggered by storm events. The islands do not fully recover from storm impacts because sand is transported to the flanks of the arc, thus removing it from the littoral system; however, these sand reservoirs may provide a unique, quasi-renewable resource for nourishing the barrier system.

Chapter E. Geologic Mapping of Potential Resources—Geophysics

Recent high-resolution geophysical surveys of the sea floor and subsurface within 5–6 km of the Chandeleur Islands during 2006 and 2007 were used to map and describe shallow stratigraphy and potential sand resources within the Breton National Wildlife Refuge. These data, in concert with

vibracore analyses, were utilized to map the distribution of the barrier island sand sheet and identify additional sand deposits that could serve as borrow areas if island renourishment is pursued.

Between 1880 and 2006, erosion dominated along the mid to southern extent of the island arc, whereas accretion has dominated along the backbarrier as washover deposits and to the north as spit growth. To date, sand accumulation onshore does not approach the pre-Hurricane Katrina sand volume of the barrier arc. Preliminary analyses of cores taken in 2007 and 2008 suggest that more sand was transported alongshore during the hurricane than moved across the island chain by washovers.

In addition to the sand that is rebuilding the island chain and closing tidal passes, a large volume of sand is contained in Hewes Point in an extensive subtidal spit platform that has formed at the northern end of the Chandeleur Islands. Hewes Point appears to be the depositional terminus of the alongshore transport system where sand is deposited in water that is deep enough for the sand to be removed from the littoral zone. In the southern Chandeleurs, sand is being transported southward from a littoral divergence zone near Monkey Bayou and is being deposited in a broad tabular deposit near Breton Island called the southern offshore sand sheet. Hewes Point (containing approximately 379 m³ of sediment) and the southern offshore sand sheet deposit account for approximately 70 percent of the estimated sediment volume located in the potential borrow sites.

An additional four potential sand resource sites within the Chandeleur Islands study area have been mapped. These four are distributary channel deposits associated with the formation of the delta upon which the islands stand. These deposits are significantly smaller in volume and generally have a lower and more variable sand content than the Hewes Point deposit. These sand deposits are in shallow enough water that sand from these deposits may potentially be redistributed by storms originating to the south.

Chapter F. Geologic Mapping of Potential Resources—Cores

The textural composition of the deposits identified by the seismic data was defined by vibracores collected throughout the northern half of the Breton National Wildlife Refuge. The textural composition of the four distributary channel deposits is a function of fluvial energy and proximity to the distributary mouth from which they were derived. The distributaries deposited sand-size sediments directly at the river mouth (mouth bar and delta front) and carried the fine-grained materials in suspension farther away from the distributaries, where they settled into extensive blankets of mud across the sea floor. The four distributary sites generally have a sand content of about 53 percent (about 47 percent mud), but the

sand content is highly variable within individual cores. The sands in Hewes Point and the southern offshore sand sheet deposits are broad tabular deposits of sand. The sands in the Hewes Point deposit are relatively clean (approximately 90 percent sand), but the sand content of the southern offshore sand sheet is unknown because no cores are available from there.

Chapter G. St. Bernard Shoals

A final large potential source of sand for restoration may lie in the St. Bernard Shoals. The St. Bernard Shoals system comprises 61 discrete sand bodies ranging in aerial extent from 0.05 km² to 44 km². Individual shoals are separated into two different fields: the larger shoal field lies in the southern part of the system in 16–20 m of water, and the smaller one lies 5 km northwest of the larger field in 15 m of water. The shoal complex is estimated to contain approximately 200×10^6 m³. The southern, larger shoal field contains 192×10^6 m³ of sand (92 percent of the total volume). Sediment analyses indicate that sand found in the shoals is fine to very fine (2–2.5 phi), tan to gray in color, and well sorted. The shoals are all very similar in distribution of sediment types which resulted from deposition in fluvial channels and are similar to and probably derived from the same source as the sediments that form the Chandeleur Islands.

Chapter H. Numerical Simulation of Waves and Sediment Transport

A numerical simulation of waves and sediment transport was undertaken to quantify the response of the island chain to low-intensity, intermediate, and extreme events, as well as their recovery after such events. The modeling output indicates that the islands are undergoing high rates of sediment transport in the northward direction during high-intensity and intermediate storms, that vast areas of the lower shoreface are affected and are undergoing erosion during these events, that there is little or no fair weather mechanism to rework material into the littoral system, and that as a result there is a net loss of sediment from the system.

Implications for Management Planning

If the decision is made to restore any portions of the Breton National Wildlife Refuge, the restoration techniques should mimic the natural processes of early stages of barrier island evolution. These natural processes include lateral transport to the flanks of the island chain from a centralized sand source that will ultimately enhance the ability of the

islands to naturally build backbarrier marsh, dunes, and a continuous sandy shoreline. Barrier island sediment nourishment should be executed with the understanding that gulf shoreline erosion is inevitable but that island area can be maintained and enhanced during retreat (thus significantly prolonging the life of the island chain) with strategic sand placement if the following criteria are met:

1. Nourishment sand recovered from deepwater sinks at the flanks of the island arc is reintroduced to the barrier sand budget at a centralized location that is chosen on the basis of longshore sediment transport predictions;
2. Distribution of naturally occurring hurricane-cut passes is maintained as storm surge/overwash pathways;
3. Sand is placed at a centralized location along the island arc where it will naturally disperse to the flanks;
4. Sand reserves are strategically placed in the backbarrier as shore-perpendicular platforms over which the island can migrate; and
5. A naturally well-established (decadal to century-scale) backbarrier vegetation is maintained for long-term sustainability.

Breton Island, because of its unique position and importance to habitat, might be treated somewhat differently. Breton Island has been sediment starved because of maintenance dredging of the Mississippi River-Gulf Outlet updrift of the island, resulting in rapid island degradation. The island is in need of immediate sand nourishment. A significant amount of sediment has accumulated downdrift (south) of Breton Island and can potentially be mined with minimal negative effect on the local hydrodynamics.

